Multidisciplinary Arctic Program (MAP) – Last Ice: Science Plan, Spring 2018 Field Campaign

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2018

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 3157

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MULTIDISCIPLINARY ARCTIC PROGRAM (MAP) – LAST ICE: SCIENCE PLAN SPRING 2018 FIELD CAMPAIGN

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Cat. Fs 97-4/3157E-PDF ISBN 978-0-660-26933-7 ISSN 1488-5387

Correct citation for this publication:

Michel, C., Lange, B. 2018. Multidisciplinary Arctic Program (MAP) – Last Ice: Science Plan, Spring 2018 Field Campaign. Can. Manuscr. Rep. Fish. Aquat. Sci. 3157: vii + 21 p.

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ABSTRACT

Michel, C., Lange, B. 2018. Multidisciplinary Arctic Program (MAP) – Last Ice: Science Plan, Spring 2018 Field Campaign. Can. Manuscr. Rep. Fish. Aquat. Sci. 3157: vii + 21 p.

The Last Ice Area (LIA) is the only Arctic region that is expected to retain summer sea ice until 2050. Due to the importance of this region, Fisheries and Oceans Canada has initiated the Multidisciplinary Arctic Program (MAP) – Last Ice Science Program, to characterize the ecosystem of the LIA. The MAP- Last Ice Science Program will develop a knowledge base of the connected sea ice-ocean system of the unique multiyear ice ecosystem north of Ellesmere Island. The first field campaign takes place in spring 2018. This report summarizes the science plan for this field campaign, detailing program elements for physical, chemical, and biological components in first-year and multi-year ice, and in the water column. This science plan served as the basis for the planning of the first field expedition in the LIA, and will help inform subsequent field campaigns.

RÉSUMÉ

Michel, C., Lange, B. 2018. Programme multidisciplinaire arctique (PMA) – Glace séculaire: Plan Scientifique, campagne d'échantillonnage du printemps 2018. Can. Manuscr. Rep. Fish. Aquat. Sci. 3157: vii + 21 p.

La zone séculaire de glace (ZSG) est la seule région arctique où il est prévu que la glace subsiste en été d'ici 2050. Étant donné l'importance de cette région, Pêches et Océans Canada a initié le Programme multidisciplinaire arctique (PMA) – Glace séculaire, afin de caractériser l'écosystème de la ZSG. Le programme PMA – Glace séculaire mettra sur pied une base de connaissances sur le système connecté glace-océan de l'écosystème unique de glace de mer multi-annuelle au nord de l'île d'Ellesmere. La première campagne d'échantillonnage a lieu au printemps 2018. Ce rapport présente le plan scientifique pour cette campagne d'échantillonnage, et détaille les éléments du programme scientifique pour les composantes physique, chimique et biologique de la glace annuelle, multi-annuelle, et de la colonne d'eau. Ce plan scientifique a servi de base pour la planification et la mise en place de la première expédition scientifique du Programme PMA – Glace séculaire, et servira à informer les campagnes subséquentes.

ACKNOWLEDGEMENTS

The Last Ice Area Science Program would not be possible without a government-wide collaborative approach, together with the support of northerners. The enormous logistical challenges to access and collect sea ice and oceanographic data in the Last Ice Area are only met through the involvement and invaluable support of the Polar Continental Shelf Program (PCSP), Natural Resources Canada; the Department of National Defense (DND) at CFS Alert Military Base, and Defense Research and Development Canada (DRDC). We also thank Environment and Climate Change Canada (ECCC) for science coordination in Alert, and the communities and Hunters and Trappers Associations of Resolute Bay and Grise Fjord. Special thanks go to Andrew Platt (ECCC), Chris Brown and Jim Milne at DRDC, Tim McCagherty, Tom Platt, Jodi MacGregor and Tanya Lemieux at PCSP and at Canadian Forces Station Alert: Major Caden Stiles, Commanding Officer (CO), Rene Hansen, Station Warrant Officer (SWO) and Rob Lutz, Alta SWO. We sincerely thank the Program's principal investigators and participants in Canada and abroad who contributed to the development of the Science Plan: Christian Haas and Hauke Flores (Alfred Wegener Institute, AWI), Karley Campbell (Bristol University), Steve Ferguson, Andrea Niemi and Clark Richards (DFO). Funding for the MAP- Last Ice Program is under DFO Science and the International Governance Strategy.

1.0 INTRODUCTION

The Last Ice Area (LIA) is the only region that is expected to retain summer sea ice until 2050. As permanent ice cover recedes, the LIA will be essential for the communities that depend on ice-dependent species for food, shelter and cultural use. This region is one of the most remote and inaccessible regions in the world and therefore is lacking baseline ecological knowledge. The Government of Canada has committed to work in collaboration with northern partners and national and international stakeholders to better understand the LIA. To this end, Fisheries and Oceans Canada (DFO) has secured funding for a 4-year (2017-2021) research program, the Multidisciplinary Arctic Program (MAP) – Last Ice, to study the LIA. Extensive field sampling is planned for 2018 and 2019, and more focused sampling is anticipated in 2020 and possibly 2021. The DFO MAP-Last Ice Program aims at characterizing the ecosystem of the LIA, a region where scientific data collection is limited and widespread ecosystem knowledge gaps exist. This study will provide a first ecological assessment of an area representative of the unique region where multiyear ice still resides in the Arctic Ocean. This knowledge is essential to understand the structure, function and role of the sea-ice associated ecosystem in the Arctic Ocean.

1.1 Program Objectives

With the on-going rapid declines in Arctic sea ice, there is an urgent need to better understand the role of sea ice in the Arctic marine ecosystem as a prerequisite to inform the sustainable management and conservation of Arctic marine resources. This program will provide scientifically-defensible ecosystem knowledge to answer the overarching question:
How does multi-year sea ice influence the structure and functioning of the LIA and Arctic marine ecosystems?
Towards this goal, the general objective is to characterize key physical, chemical and biological processes including sea ice-associated biodiversity, habitat and habitat usage, in the LIA.
Specific objectives are to:

- Compare the composition, biodiversity, and activity of biological assemblages in first-year and multi-year ice in the LIA;
- Determine the carbon uptake and composition of organic carbon constituents in first-year and multiyear sea ice, and its cycling in the LIA;
- Characterize the water column physical, chemical, and biological properties during the spring ice-covered period in coastal waters of the LIA;
- Assess the composition, abundance and distribution of zooplankton and under-ice fauna during the spring ice covered period, in the LIA;
- Evaluate the presence and distribution of marine mammals and their habitat usage offshore of Ellesmere Island.

DFO is working collaboratively with partners in Canada and internationally, to provide an integrated ecosystem overview of the LIA, combine multifaceted sampling and analytical

approaches, and integrate new technologies for an observational and relational study of the sea ice and marine ecosystem. In particular, DFO-AWI's collaborative approach includes, but is not limited to:

- An integrated assessment of biochemical measurements (DFO) with optical and physical measurements (AWI) obtained with a remotely operated vehicle (ROV) to characterize sea ice habitat types;
- Parallel and complementary sampling approaches to characterize zooplankton communities, with vertical tows and AZFP (DFO) and ROV measurements and horizontal tows (AWI).

2.0 PROGRAM PARTICIPANTS

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Jana Hildebrandt (AWI)
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Ron ten Boer (AWI)

3.0 SAMPLING PLANS

3.1 Field observations and survey program components

The spring 2018 Alert field campaign that will take place from April 25th to June 6th. The specific objectives outlined above will be addressed through five complementary program components described in the following sections:

- Spatially-distributed sea ice habitat and productivity
- Temporal evolution of the ice and under-ice habitat
- Continuous atmospheric, oceanographic and sea ice observations

- Zooplankton, fish and benthic organisms
- Marine mammals and habitat surveys

A large part of the spring 2018 field sampling will be conducted at a sea ice station where we will set up a temporary sampling and laboratory Weatherhaven tent and a shelter for instrumentation. The DFO team will travel by snowmobile daily to the station and carry out the sampling and the immediate processing of sea ice (cores) and water samples in the semi-clean laboratory tent, over a sampling period of ca 4 weeks. Main activities at camp include the collection and processing of spatially-and temporally-distributed sea ice samples (program components 1 and 2), regular water column sampling for water physical properties (Conductivity, Temperature and Depth), biochemistry and zooplankton abundance (program components 2 and 4), the deployment of autonomous observation systems (e.g., ice-tethered oceanographic mooring, meteorological station, and snow/ice buoy, work package 3), sea ice habitat characterization surveys using an unmanned aerial vehicle (UAV), and marine mammal aerial surveys (program component 5). Additional planned activities include the possible deployment of an ice buoy on multiyear ice at a remote location, DFO partners from AWI will conduct under-ice surveys using a remotely operated vehicle (ROV) linking physical and biological properties in and under the ice, partners from the Bristol, UK will provide complimentary productivity and biodiversity measurements, partners from Essex, UK will characterize sea ice carbon constituents, and partners from ECCC will investigate the presence of mercury in snow and biota.

3.2 Spatially-distributed sea ice habitat and productivity

This program component will evaluate suitable habitat for productivity (proxy: biomass) in types of ice (e.g. hummocks, FYI) and compare biological properties in different ice types within the LIA. The sampling requires the characterization of physical and biological sea ice conditions in spatially distributed transects along gradients of conditions from hummocked ice to first-year ice. In order to obtain light measurements under undisturbed snow and ice cover, this work will be coordinated with the use of the ROV for under-ice light measurements and snow/ice thickness measurements.

The general sampling plan is to collect core samples along transects to characterize three ice habitats (hummocks, fringe, and multiyear refrozen pounds) where the under-ice light is characterized beforehand with the ROV. The biochemical ice core sampling will involve collection of 5 (five) ice cores in each of the three habitats, accompanied by ROV spectral light measurements in and under the ice, snow and ice measurements. The biological measurements will be linked to light in particular, by conducting under-ice light measurements along the gradient of conditions (i.e. habitats) prior to sampling, ensuring measurements are conducted in an undisturbed environment. In-ice scattering observations, ROV laser scanning, magna probing, and ice bottom topography measurements will also be carried out.

This work will be repeated on three occasions during the sampling season (ca 12-14 days interval), to provide for seasonality in these habitats. For each habitat type, one core will be analyzed for bio-optics, i.e. the core will be cut in 10 cm sections, each section analyzed for biochemical variables and spectral light transmission (see Table 1). Four (4) additional cores will be collected in each sae ice habitat type, with bottom cores analyzed individually to assess intra-habitat variability, and bulk core sections (3 sections per core) analyzed for a full suite of biochemical properties to characterize each habitat type (see Table 1). On an irregular basis, additional cores may be collected to measure variables that require large amounts of organic material, such as particulate organic carbon or fatty acid biomarkers.

The comparison between different ice types, progressing from hummocks to the outer fringe of hummocks and multiyear ice will allow us to integrate physical factors (AWI) and their influence on sea ice biomass, composition, and production (DFO). The data collection and analytical approach is developed to test the following hypotheses:

H_1: Hummock ice has higher ice algal biomass than fringe and refrozen melt pond multiyear ice, in early spring.

H_2: Bottom ice biomass in multiyear ice is positively correlated with irradiance, in early spring.

Planned statistical analyses include: but are not limited to ANOVAs comparing biological properties for three ice types and three core sections and correlation analysis between bottom sea ice biomass/production and optical/physical properties.

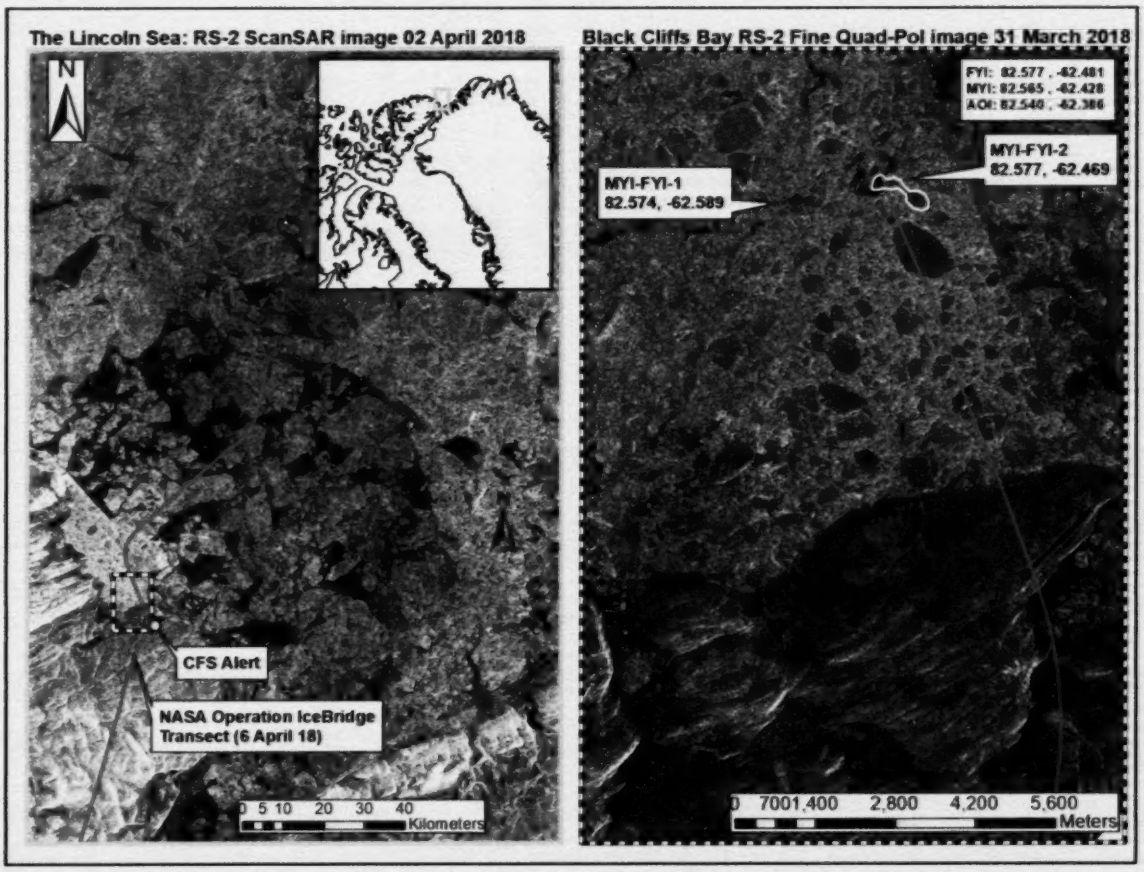

Figure 1. Proposed station sites in the Lincoln Sea, off CFS Alert, allowing for multi-year and first-year ice coordinated sampling. Red line shows NASA Operation IceBridge; MYI: Multi-year site; FYI: First-year site; AOI: Area of Interest.

Table 1. Biochemical measurements and leads for sea ice habitat characterization (Program Component 1). Sampling plan is for 3 habitats, 5 cores per habitat and 3 sampling date throughout the season, for a total of 15 cores per sampling day. Intra-habitat variability is accounted for in the sampling plan. Rep is for replicate samples.

Ecosystem Component	Variable	Full core	Hummocks bottom cores	Fringe bottom cores	MYI or FYI bottom cores	Rep	Lead
Standing stock - Algal biomass	Chl *a*[1]	x	x	x	x	2	DFO
Carbon cycling	DOC[2]	x	x	x	x	2	DFO
Species diversity	Cell taxonomy & counts[3]	x	x	x	x	2	DFO
Genetic diversity	DNA/PCR*		x	x	x	2	DFO
Community structure - prokaryotes	Bacteria abundance & nucleic acid content[4]	x	x	x	x	2	DFO
Community structure - eukaryotes	Protist abundance & functional groups[4]	x	x	x	x	2	DFO
Community structure - viruses	Viral abundance[4]	x	x	x	x	2	DFO
Nutrients	PO_4, $SiOH_4$, NO_3+NO_2	x	x	x	x	2	DFO
Habitat availability	Temperature (for brine)	x				1	DFO
Habitat	Salinity / 18O	x	x	x	x	1	DFO
Carbon Cycling	POC	x	x	x	x	2	KC
PE incubation	PE	x	x	x	x	3	KC
Light availability	2D Ice thickness 2D Snow thickness 2D under-ice radiation	n/a	x	x	x	1-3	AWI

[1] Total chlorophyll a (GF/F filters)

[2] High-temperature catalytic combustion

[3] Inverted microscope, Utermöhl method

[4] Flow cytometry

3.3 Temporal evolution of ice and under-ice habitats

This program component will evaluate temporal changes in physical, chemical and biological properties at the ice surface (i.e. air temperature, snow), within the ice, and under the ice (water column) during the spring period.

The ice and water column sampling will be carried out every 4 days, providing a time-series of biological and chemical observations, in addition to continuous measurements described below.
On each sampling day, we will collect ice cores in MYI (corresponding to the spatial habitat sampling above) and FYI areas (different than the spatial sampling above, thereby allowing a comparison of the two types of ice, and their seasonal evolution.
Because ice cores are vertically heterogeneous, for example the bottom of MYI cores is actually ice that has formed during the same year (FYI) whereas the top of the core is multiyear ice that remains from one or more previous sampling year(s), we will collect a minimum of 2 sections (mid-core and bottom) and ideally 3 sections for each type of ice. For each sampling site (MYI and FYI) and core section, we will measure a full suite of bio-chemical variables to assess environmental conditions, biomass, biodiversity and productivity (see Table 1.1). For this component, we will collect 6 cores per ice type. The cores, cut into sections will be combined for a full suite of biochemical measurements on 3 sections of the cores. In as much as possible, core collection should be in the vicinity of ROV sensor measurements which comprise nitrate, salinity, temperature, chlorophyll, CDOM, backscatter @700nm, oxygen, hyperspectral light extinction, and occasionally water velocity.

Water column sampling will be done every 4-d. A CTD (Seabird 19) cast will be carried out first, followed by Niskin bottle sampling at surface and 4 depths. Targeted sampling depths are 10, 25, 50 and 100 m, dependent on water depth at station. Order of sample collection follows established oceanographic protocols, with DIC/TA samples collected first, then nutrients, and biological parameters. Processing of samples will be carried out in the field laboratory tent to ensure samples are least disturbed and processed quickly after collection.

Table 2. Biochemical measurements in ice core sections and the water column for temporal evolution of sea ice and under-ice properties (Program Components 1 & 2). Note that ice habitats targeted mesh with ice habitat characterization in Component 1 (also see Table 1). Rep is for replicate samples.

Ecosystem Component	Variable	MYI (2 or 3 sections)	FYI (2 or 3 sections	Surface water	Water column (4 depths)	Rep	Lead
Standing stock - Algal biomass	Chl *a* tot	x	x	x	x	2	DFO
	Chl a > 5 µm			x	x	2	DFO
Carbon cycling	DOC	x	x	x		2	DFO
	POC/N & 13C/15N			x			
	DIC / TA			x	x		
Species diversity	Cell taxonomy & counts	x	x	x		2	DFO
Genetic diversity	DNA/PCR	x	x	x		2	DFO
Community structure - prokaryotes	Bacteria abundance & nucleic acid content	x	x	x		2	DFO
Community structure - eukaryotes	Protist abundance & functional groups[4]	x	x	x		2	DFO
Community structure - viruses	Viral abundance[4]	x	x	x		2	DFO
Primary Production	15N / 13C uptake	x	x			2	DFO
Nutrients	PO_4, $SiOH_4$, $NO_3 + NO_2$	x	x	x	x	2	DFO
Habitat availability	Temperature (for brine)	x	x			1	DFO
Habitat	Salinity / 18O	x	x	x	x	1	DFO
Carbon cycle	Carbohydrates	x	x			3	DFO/ Essex
Additional measurements							
	POC/PN & 13C /15N	x	x			3	DFO
	Fatty acids	x	x			3	DFO

3.4 Continuous atmospheric, oceanographic and sea ice observations

A series of instruments will be deployed for the continuous monitoring of environment and oceanographic conditions at the main station. DFO is planning to deploy 3 moorings and one ice-mounted meteorological station at the sampling site. We plan to deploy a Sentinel V Acoustic Dopppler Current Profiler (ADCP), installed at 1 m under the ice, looking downward, for the duration of the spring sampling program. An downward looking, ice-tethered Acoustic Zooplankton Fish Profiler (AZFP) will also be deployed ca. 1 m below the ice during the same period.

A multisensory mooring with two CTDs Seabird SBE16 equipped with WetLabs Eco triplet fluorescence will be deployed on one mooring line, at 1 and 25 m (tentative depth) under the ice cover. In addition to these moorings, we will install a meteorological station at the sampling site, to continuously monitor weather conditions (e.g. air temperature, relative humidity, atmospheric pressure, wind speed and direction, and downwelling and upwelling radiation), possibly linking to under-ice radiation. A camera mounted on a tripod on the shore will provide a time-series record of conditions and their evolution over the spring sampling and throughout summer and fall.
These moorings will provide continuous observations at the site, supporting DFO and DFO partners' biophysical measurements throughout the spring period.

AWI will deploy two spectral radiation stations (incoming/reflected and under-ice transmitted irradiance) at the MYI and FYI site. This will be accompanied by two snow buoy deployments and an ice-mass balance buoy. DFO also has a SIMBA ice-balance buoy that will complement these measurements.

3.5 Zooplankton, sea-ice fauna, fish and benthic organisms

Regular (every 4-d) collection of zooplankton will be carried out from the biological sampling laboratory tent using vertical tows with a 153 µm net. Any larval fish with be removed and frozen for analyses and the bulk community will be kept preserved with borate buffered formaldehyde (P.I: A. Niemi). If sufficient biomass is present, additional tows could be taken to collect and freeze samples for mercury, stable isotopes (SI) and/or fatty acid (FA) analyses. Samples will be brought back to the DFO main laboratory in Winnipeg for analysis. Since this work is exploratory in nature, we cannot anticipate how much zooplankton will be collected. Canadian and international partners (Steffen from EC and Heimburger from Europe) are planning to collect zooplankton for mercury analysis, in collaboration with DFO. During ROV dives coincident with the zooplankton sampling, AWI plans horizontal under-ice trawls at the ice underside, as well as in 5 and 10m depths.

Following the same sampling scheme as the zooplankton sampling, under-ice fauna will be sampled with a 150 µm net mounted on the AWI ROV ("ROVnet"). This net will be towed

horizontally for 100-300 m long profiles at 3 sampling depths: ice-water interface; 5 m and 10 m. Concurrently with the sampling, the ROV collects the full suite of sensor data for later integrated analysis. The samples will be primarily preserved on 4% buffered formaldehyde-solution for later analysis at AWI. On an opportunistic basis, individual animals will be collected for biomarker, stable isotope and DNA analysis. If time is available, the following opportunistic sampling will be performed by the AWI team: sampling of ice cores for investigations of sea ice meiofauna. For this, the bottom 10 cm of ice cores will be melted and subsequently concentrated and stored in 4% formaldehyde solution.

3.6 Marine mammals and habitat surveys

Marine mammal surveys will be conducted north of Alert from May 28 to June 6th, depending on weather conditions. The survey team is composed of Brent Young, Melissa Galicia and Cody Carlyle, under the direction of Steve Ferguson (DFO). The aerial survey will be conducted with a Twin Otter equipped with a camera, and will target the ice edge area where marine mammals are expected to congregate. This work is exploratory in nature since there has been no previous marine mammal survey in the area.

In addition, mesoscale habitat surveys will be carried out with an unmanned aerial vehicle (UAV) carrying a visible and an infrared camera, to simultaneously assess the presence of fauna (e.g,. seals) and the snow/ice conditions.

4.0 USE OF NEW TECHNOLOGY AND LINKS TO MODELLING

We will measure physical and biological properties of the sea ice and water column during the spring and fall period, and use a comparative approach to study the different types of ice (e.g. MYI vs FYI) within the LIA. The field observations will help constrain biogeochemical models that currently lack adequate parameterization for multiyear ice. An important component of the field program is to acquire continuous, long-term observations of key physical and biological processes, using ice-tethered autonomous moorings. These observations will be complemented by extensive airborne and satellite remote sensing studies (C. Haas, YU/AWI), allowing for upscaling of in situ observations to larger regions. We also plan to carry out two exploratory marine mammal surveys, one in the spring and one in the fall, complemented by the use of a UAV.

Three DFO team members have completed UAV training prior to the field program and will be able to operate the UAV at mesoscale (visual). The UAV will be flown in systematic overlapping grids, with visual, thermal infrared and multi-spectral cameras. The data will be used to create 3-dimensional topographical maps of the snow and sea ice surface. In combination with the 3D surface topography maps, the spectral and thermal properties of the sea ice retrieved from the multi-spectral and thermal infrared cameras will inform the identification and classification of different sea ice features and ice types (e.g., sea ridges, hummocks, and MYI vs. FYI). Flying the

UAV at distances of <1 km and conducting more linear transect type survey configurations with the thermal infrared camera we will be able to identify the distribution/occurrence of marine mammals (e.g., ringed seals and polar bears), and investigate linkages with sea ice habitat properties.

Figure 2. Unmanned aerial vehicle equipped with multi-spectral, infra-red and visible cameras for the exploratory mapping of sea ice habitat.

5.0 LOGISTICS

5.1 Fuel in Alert

In order to support the marine mammal survey as well as equipment and personnel mobilisation / demobilisation in Alert, Polar Continental Shelf Program (PSCP) successfully arranged for DFO the delivery of 31 609.8L of fuel to Alert in February 2018. The request for delivery of Jet fuel to Alert was identified during the LIA Logistics Workshop in Ottawa in January 2018 (Lange and Michel, 2018). We are very thankful to our PSCP partners, their efficient and experienced logistical team, for organizing this challenging task in record time. We are planning to request another shipment of ca 30 000L of Jet fuel to Alert in 2018-2019 in preparation for marine mammal surveys in fall 2018 and for the spring survey in 2019.

Gasoline for snowmobiles in Alert: DFO requested 4 drums of gasoline delivered to Alert by PCSP for travel to/from the sampling site by snowmobile (C. Michel PCSP application, November 2018). A late request (February 2018) for another 4 drums of gasoline for AWI partners is being accommodated by PCSP-DFO.

5.2 Ice camp set up and logistics

We are thankful to DRDC and DND for organizing the logistical support for the set up and functionality (e.g. diesel furnace, generators deployment holes) of our temporary ice camp and laboratory offshore of Alert. DRDC also provides important equipment for this field program, including snowmobiles, komatics, and other field equipment in Alert. The help and equipment provided by DRDC to facilitate our sampling makes it possible to carry out this extensive sampling program.

5.3 Safety and Security

Safe Work Procedures for general safety at camp, including project-specific potential hazard and mitigation procedures, are attached in Appendix 1. A spill response and mitigation plan is included in Appendix 2.

DFO is responsible for the safety and security of DFO personnel. All DFO personnel, including post doctorate fellows and students, have security clearance, required for work in Alert. All DFO personnel, including postdoctorate fellows and students, have received appropriate training for the field work, including First Aid CPR Level C and Automated External Defibrillation. Most DFO field participants have a valid Firearm Possession and Acquisition Licence (PAL). Throughout the sampling program, one DFO team member will be responsible for the firearm in the field (bear safety) and has a firearm practical training in addition to a PAL.

DFO has developed a Safety Plan for the MAP-Last Ice Field Program, acknowledged by all DFO participants to the field program. First aid and safety kits and are available at the ice camp and are carried during snowmobile transportation to/from the field. We oblige by the "buddy rule"; safe

practices in the field and in the laboratory, and follow the guidelines as per NIRB and NRI licensing.

5.4 Licensing

DFO licensing for the MAP-Last Ice 2018 field campaign includes the collection of ice algae, phytoplankton, minimum amount of zooplankton, and benthos, and was obtained through multiple levels of approval:

DFO License to Fish for Scientific Purposes S-18/19-1000-NU

NIRB Screening (File 18YN002)

Nunavut Research Institute Scientific Licence 02 040 18R-M

Resolute HTA Letter of Support

6.0 REFERENCES

Lange, B., Michel, C. 2018. Multidisciplinary Arctic Program (MAP) – Last Ice: Science Logistics Meeting Report, Spring 2018 Field Campaign. Can. Manuscr. Rep. Fish. Aquat. Sci. 3156: vii + 12 p.

Appendix 1. Safe Work Procedure - General Safety at Ice Camp, Spring Campaign 2018 Last Ice Program

The following general safety procedures are developed to best prevent and mitigate Potential Hazards and Risks to Health associated with field work at ice stations or at ice camps. General Safety Protocols and field check lists are described as they provide essential prevention and mitigation measures. Specific Safe Work Procedures (SWPs) are referred to when applicable.

General Safety Protocol:

- Assessment of daily weather & ice conditions – current and predicted to determine if it is safe to travel to field station that day.
- Always a minimum of 2 snowmobiles + 1 komatic travelling to /from field. DFO team members should travel together and carry the firearm (under the supervision of the responsible team member) when travelling to/from the ice
- Always follow the same marked trail to travel between station and Alert base
- Ice station has warm shelter with generator, safety kits, heater, etc.
- Scheduled call in at set check-in times ensures regular contact with Alert base. Alert base should know at all times where everyone in the party is. At minimum, check in when leaving Alert base, check in when arriving at ice station, check in when leaving ice station, check in when arriving in Alert. Account for location of all team members.
- Proper winter clothing plus spare mitts etc. worn/taken for field work
- All team members will keep vigilant polar bear watch to ensure everyone's safety. Predetermined team member is responsible for firearm.
- For polar bear watch and safety, in addition to the above, protocol is to do a perimeter survey before starting work at station (could be done with drone and snowmobiles), then regular surveys, e.g., every three hours. Also see SWP – Polar Bear
- A satellite phone will be available at field station to request help as required, a list of emergency contacts will be on hand.
- A PLB will be carried by team travelling to/from station at all times (2 PLBs available) in case of need for a distress signal
- DFO Marine Productivity personnel have received First Aid wilderness training
- Survival gear including GPS, satellite phone, shelter equipment, polar sleeping bags, extra clothing, emergency food, are carried on all snowmobile trips to/ from ice station.
- Flight plans are known and approved by PCSP / Alert Station; flights in approved aircraft only

Project Specific Potential Hazards and Risks to Health:

Risk of encounters with polar bears while working on the sea ice

Mitigation measures:

SWP - Polar Bears

General SWP:

When the presence of polar bears can be an issue, specific safety measures are applied at camp:

All outside activities at camp require the use of the "buddy system". This means that activities outside are carried out in group of 2 or 3 persons. For prolonged activities, e.g. sampling, a group of three is required, with one person specifically dedicated to polar bear watch. At all times, a person should inform others of their whereabouts. For example, when a person goes outside for temporary activity (e.g., going to the "bathroom tent"), this person informs others who can keep track. No wandering around alone is allowed when polar bear presence can be an issue.

- Everyone checks for polar bears; if possible there is one dedicated polar bear observer
- Do regular checks for polar bears and polar bear tracks in vicinity of ice camp / ice station
- A fence is installed around the perimeter of the living parcoll whenever possible
- DFO personnel at camp are trained for firearm use (PAL licence). Practical training is strongly recommended.
- Everybody at camp is briefed on the use of firearms. Practice, with or without ammunitions, will be done prior to/at the beginning of the field season and at camp on a regular basis as deemed necessary. If polar bears are a recurrent issue, this practice will be part of routine activities (e.g., daily).
- Potential polar bear attractants are removed. All garbage is taken outside the living parcoll every evening. Garbage is put in a sealed container away from the camp site. No food attractants such as tuna sandwiches.

Risk of injury due to snowmobile travel on sea ice

Mitigation measures:

General SWP:

- Only experienced snowmobile operators are allowed to drive the snowmobiles.
- Helmets are provided for all operators/passengers.
- Rough terrain limits the speed to < 20 km/h, which reduces risk of injury if an accident occurs.

- Snowmobiles are inspected daily; spare parts are available and a safety kit is carried at all times.
- Travel is done in groups; always 2 snowmobiles at minimum travelling together to/from ice station.
- An emergency, safety and survival kit, including satellite communication, shelter, sleeping bags and first aid kit, is carried with the team at all times (see Emergency Kit list of equipment)

Risk of injury when using mechanical equipment

Mitigation measures:

General SWP:

- Equipment is inspected daily and spares are available
- Proper training in use of equipment reduces risk of misuse or loss
- Team members are familiar with equipment and follow safety protocols when using mechanical equipment
- Team members remain alert and warm when using mechanical equipment regular health/warming breaks are implemented as required.

Risk of cold-related injuries while working in the Arctic

Mitigation measures:

General SWP:

- Decision to initiate/cancel work is made according to current and forecasted weather conditions, including wind chill
- Arctic parkas and outerwear are worn by all team members to reduce the risk of hypothermia
- Extra dry clothing (e.g., mitts) are brought in the field and available for team members
- Team personnel has first aid training adapted to field conditions including treatment of hypothermia.
- Products such as warmers (e.g., hot pockets) are available for team members to reduce the risk of frost bite for extremities
- Emergency gear including satellite communication, shelter and sleeping bags are carried with the team at all times.

Risk of injury or death in charter, Twin Otter or commercial aircraft travel

Mitigation measures:

General SWP:

- PCSP/DND staff determine if conditions are adequate for flying when required.
- Assurance from the pilot that the Twin Otter is mechanically sound as well as a personal visual check before flight.
- All personnel boarding an aircraft receives Aircraft Safety Orientation upon boarding and follows safety procedures in case of emergency

- Team members bring food and warm clothing for sea ice surveys / travel.

Snowmobile travel check list:

- Prior to departure, always advise Base Station of time of departure and estimated time of arrival.
- Make sure that the snowmobiles are re-fuelled and that the oil is checked before leaving.
- Always travel with two snowmobiles and at least one komatic (in case of snowmobile break-down).
- Always carry a survival kit that includes the following:
- Survival food packs and drinks (e.g., granola bars, dried food, dried nut mixes, hot tea and water)
- Emergency blankets
- Extra batteries for GPS
- Safety kit
- GPS with position of the camp and position of destination (e.g., PCSP)
- Sat. phone
- Gun with ammunitions
- Extra gasoline container
- Extra oil for snowmobile + emergency repair kit (e.g., spark plug, belt)
- Sleeping bag and possibly extra clothes (e.g., dry mitts and socks)

Emergency Contingency Plan:

In the event of serious injury, accident, or other safety/health related occurrence:

- Contact Alert base personnel for immediate assistance by radio.
- If contact fails or is not possible (e.g., on travel to/from station), contact will be made by satellite phone to request assistance or evacuation.
- If contact fails and the emergency is life threatening, the PLB will be activated.

Local Emergency Contacts:

Name	Organisation	Telephone No.
Alert Station –Lab Operator		623-945-3145 ext 3243
PCSP resolute	NRCAN	867-252-3872

Appendix 2. Spill Response and contingency plan for field activities near Alert, NU

Activity	Type of fuel	Mitigation / Spill Contingency Plan
All activities	All	The Alert Base Station has a Spill Response Plan which all field participants follow. If more than 1L of fuel is spilled, the Hazmat personnel is informed for immediate spill response. There will be a spill response kit at the field station.
Travel by snowmobile between Alert & sampling site	Gasoline	Station is located in proximity to Alert Base such that re-fuelling is not required at station or in transit. Snowmobile fueling takes place at Alert Base. We will carry a 20L container of gasoline in case of emergency but, based on previous experience, we do not anticipate having to refuel on the ice. In the event we would have to refuel, we will use absorbent pads to collect potential minor drips during fueling.
Ice augering	Gasoline	Refueling of ice auger takes place once per day of sampling. This activity will done prior to going to the augering site, using absorbent pads to collect potential minor drips during fueling.
Generator usage	Diesel	Refueling of the generator (expected to take place once per day based on anticipated usage) will take place over a drip pan, with absorbent pads for potential minor spills.
Heater	Diesel	The tent heater requires a 205 L diesel fuel drum which will be in containment for potential minor drips/spills. A drip pan and absorbent pads contain potential drips/minor spills at fittings to the furnace.